Atmospheric Composition and Chemistry-Climate Interaction

Advanced Technology Workshop
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The Two Top-level Questions

- How will stratospheric ozone respond to decreasing amounts of ozone destroying industrial chemicals and increasing amounts of greenhouse gases?

  A reduction in stratospheric ozone amounts leads to an increased flux of ultraviolet radiation at the Earth's surface, with harmful effects on human health and plant and animal life.

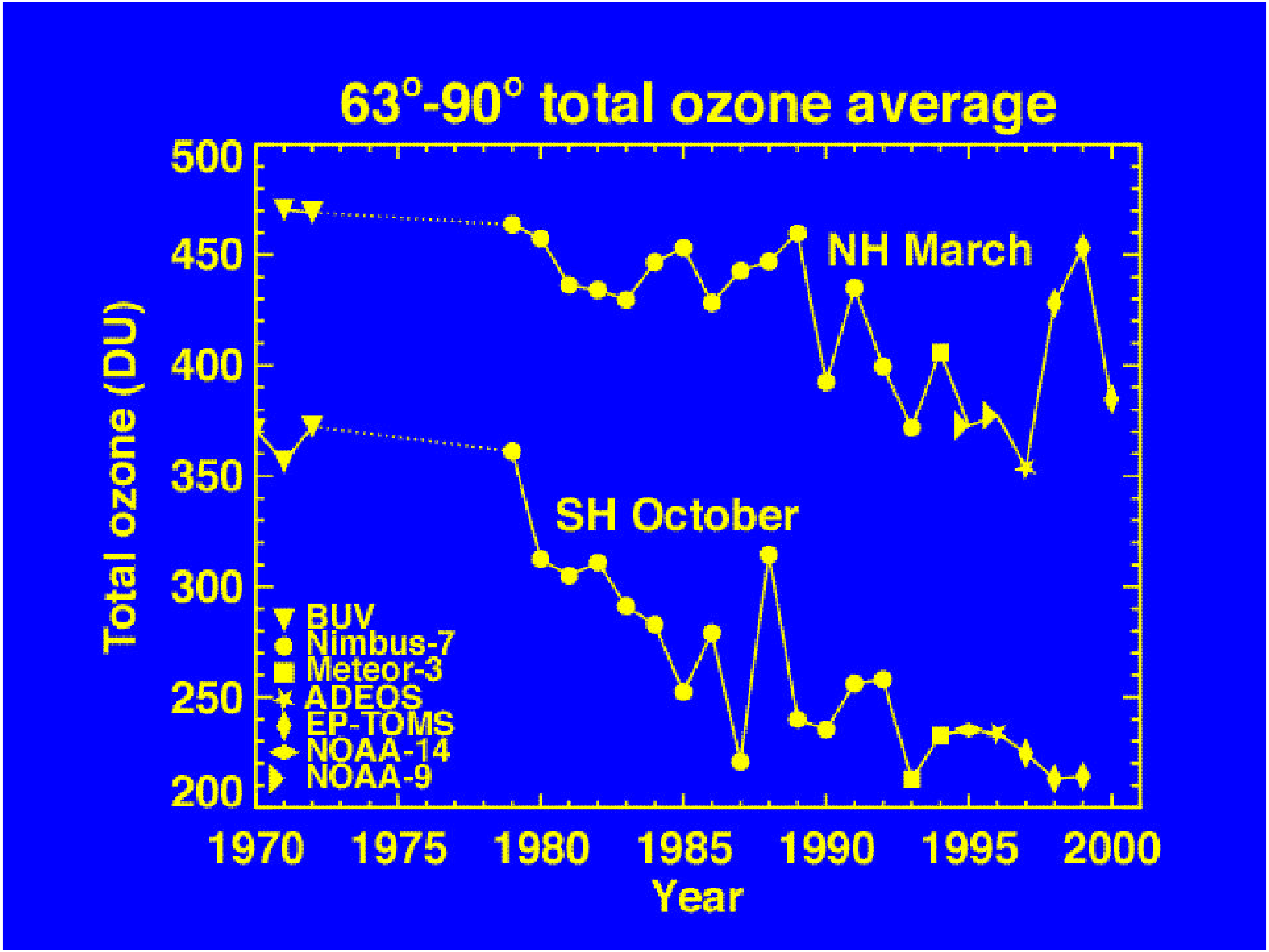
- What are the effects of regional pollution on the global atmosphere, and the effects of global chemical and climate changes on regional air quality?

  Human activity is affecting the global chemical composition of the Earth's atmosphere, and we need to know the implications for climate and human welfare

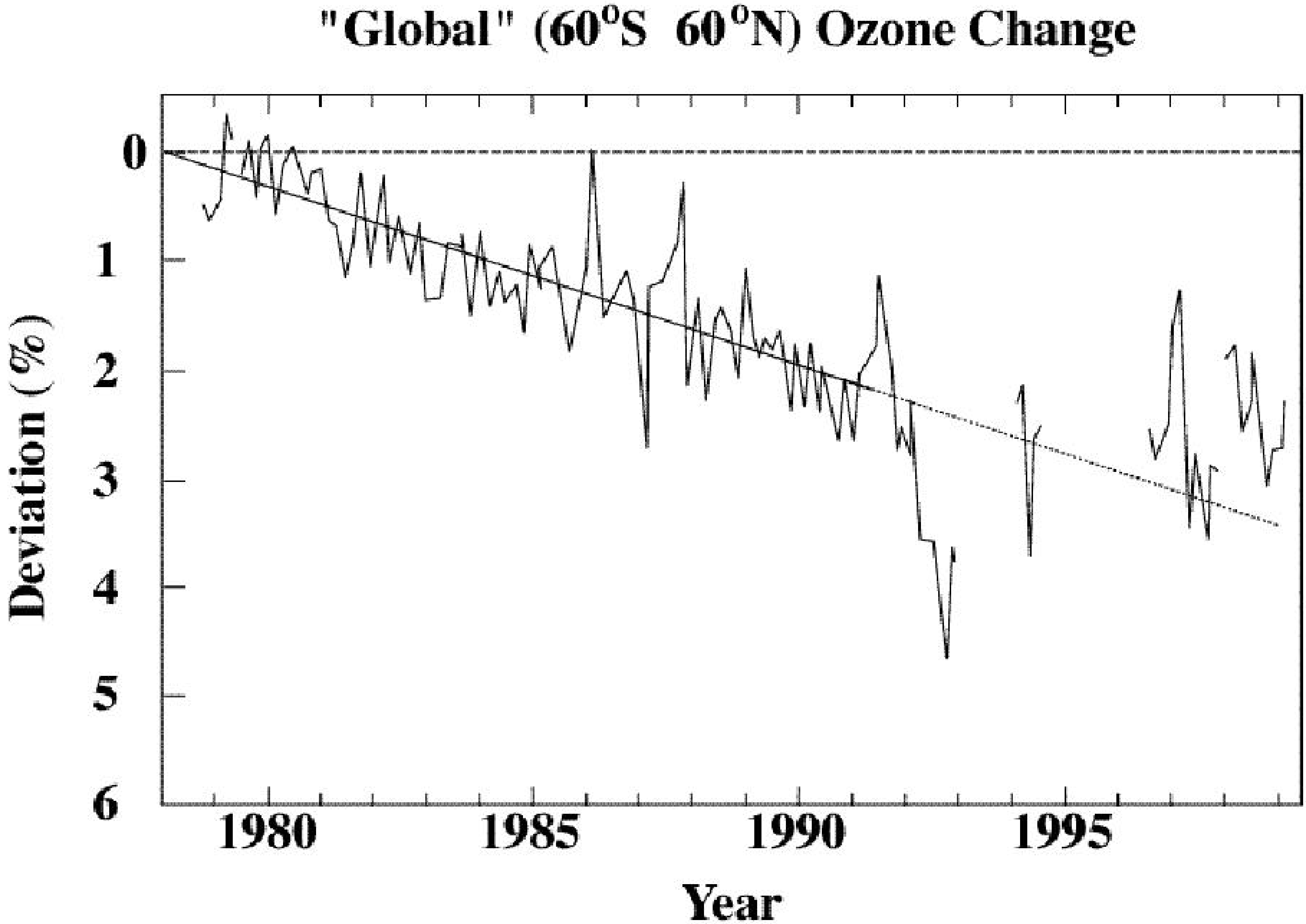
What we know

Stratospheric Ozone Change

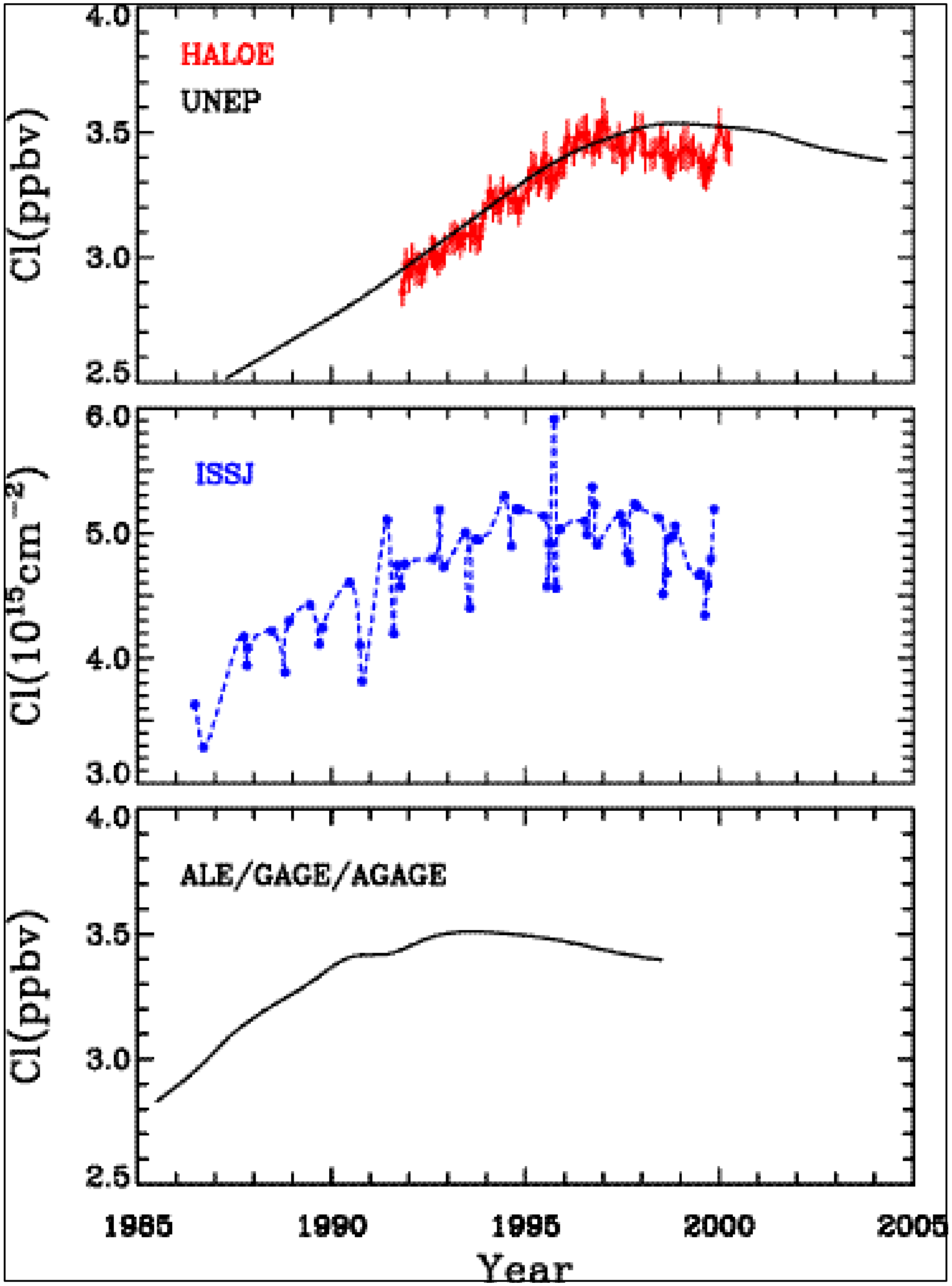
- Declining abundance of stratospheric ozone in the polar regions
  - Antarctic ozone hole
  - Frequent, large winter/spring reductions in the Arctic
- Declining abundance of global average stratospheric ozone (60 N to 60 S)
  - 2% per decade since the late 1970s
- Concentrations of ozone destroying chemicals are slowly beginning to decrease
- The chemistry of polar stratospheric ozone loss is generally understood



63°-90° total ozone average
Total ozone (DU)
500
450
400
350
300
250
200
1970
1975
1980
1985
1990
1995
2000
Year
NH March
SH October
BUV
Nimbus-7
Meteor-3
ADEOS
EP-TOMS
NOAA-14
NOAA-9



"Global" (60°S 60°N) Ozone Change
Deviation (%)
0
1
2
3
4
5
6
1980
1985
1990
1995
Year

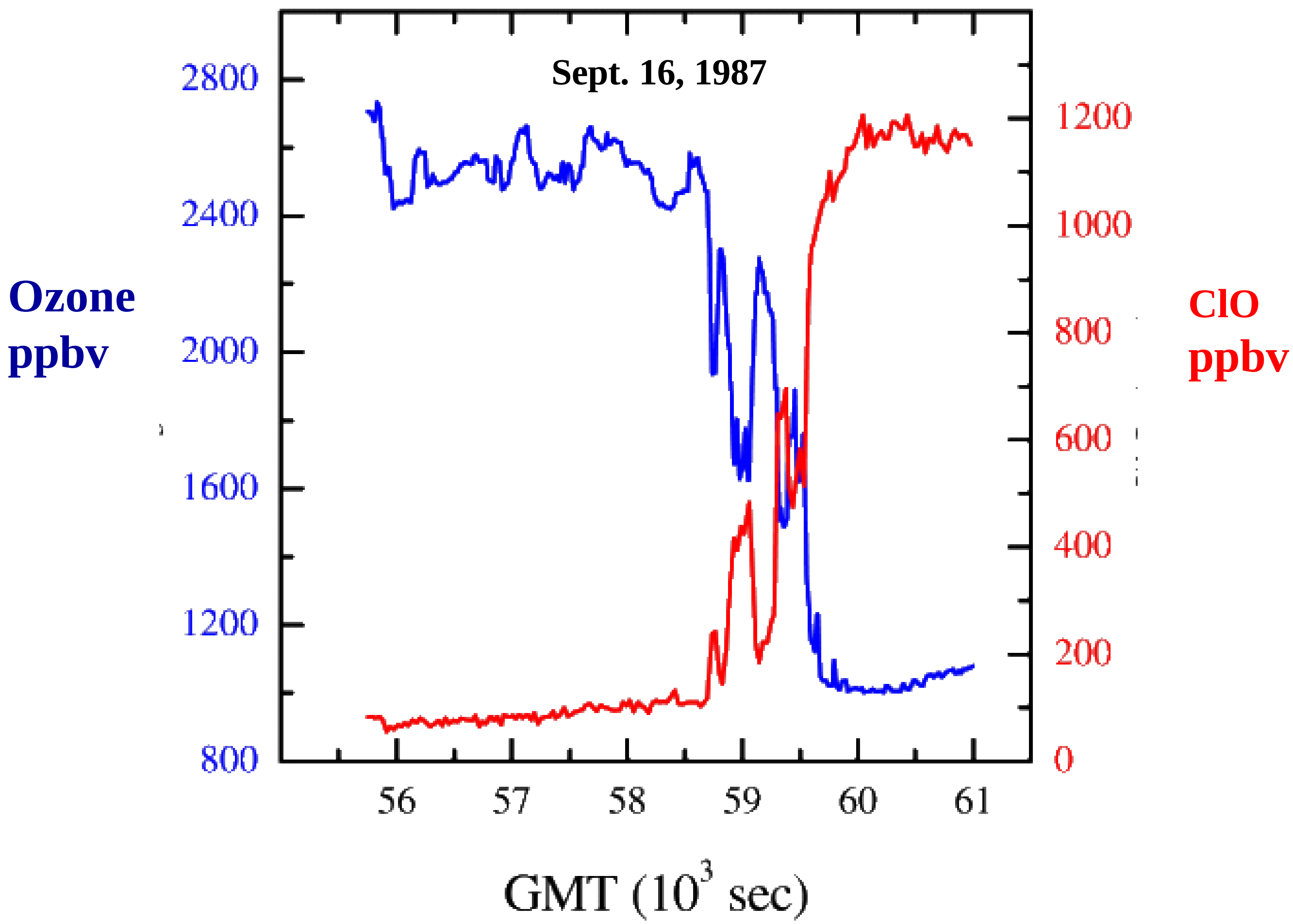


Time series of total Chlorine from HALOE compared with UNEP baseline emissions scenario time-lagged 5.3 years (Anderson et al., 1999)

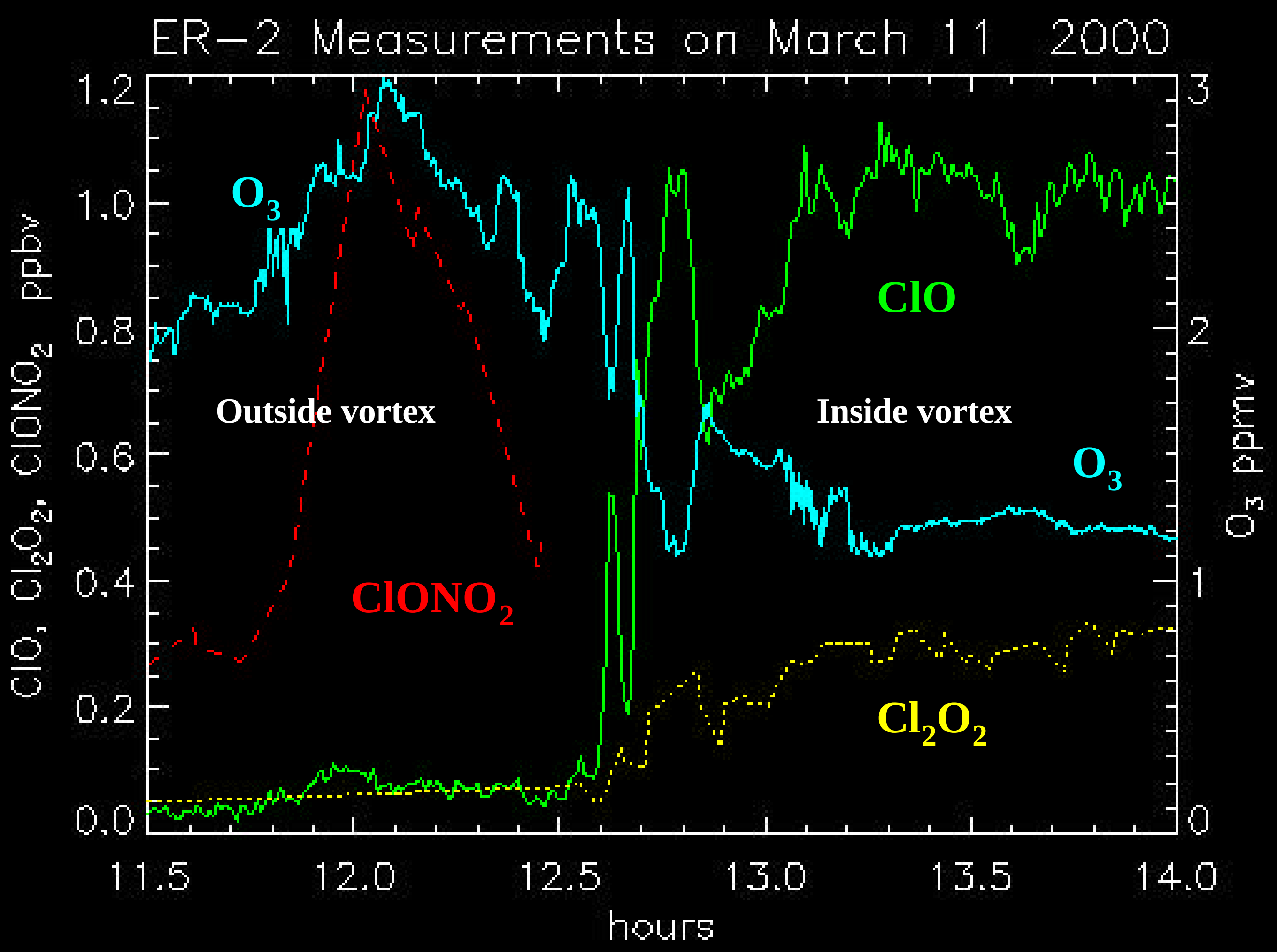
Ground-based remote-sensing Jungfraujoch column amount (Zander, 1999 personal communication)

ALE/GAGE/AGAGE ground-based in situ sampling (Prinn et al., 1998)

AAOE 1987 Antarctic Measurements



SOLVE Chlorine -Ozone Relationship



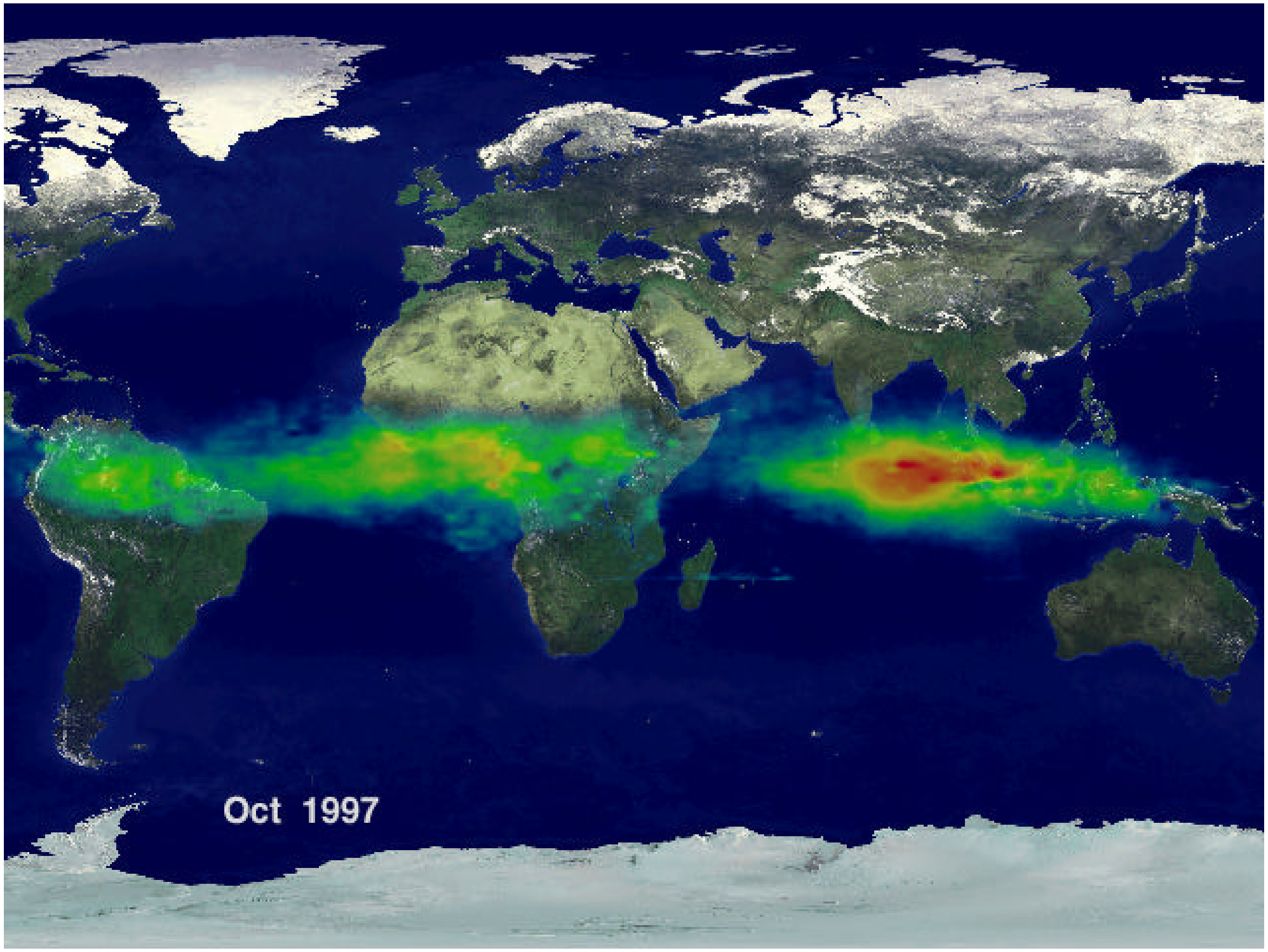
What we know

Global Pollution

- Amounts of greenhouse gases and aerosols are increasing globally
- Long-range transport of pollution affects atmospheric composition on a global scale
  - Agricultural fires
  - Industrial and urban pollution
- Cleansing of the atmosphere is controlled by the Hydroxyl radical (OH)

New TOMS Tropospheric Ozone Products

Tracking Biomass Burning during 1997 El Nino



References:

A.M. Thompson and R.D.Hudson, J.Geophys.Res., 1999.

S.Chandra et. al., Geophys. Res. Lett., 1998.

What will EOS and other missions tell us?

- Extension of the long-term record of high-precision global total column and profile abundance of ozone [TOMS, SAGE, OMI]
- First global observations allowing quantification of stratosphere-troposphere exchange processes [HIRDLS, MLS, TES, OMI]
- Identification of the chemical and dynamical processes that govern the amount and global distribution of water vapor in the stratosphere [AIRS, MLS, TES, HIRDLS]
- Quantify the contributions of chemical versus dynamical processes to global mid-latitude lower-stratospheric ozone loss [HIRDLS, MLS, TES, OMI]
- First global survey of the vertically resolved distributions of tropospheric ozone and its key precursor species H_2O, CO, CH_4, nitrogen oxides [MOPITT, TES, OMI, HIRDLS]
- Baseline distribution and optical properties of aerosols in the global atmosphere [PICASSO, MODIS, MISR, SAGE, HIRDLS, TOMS, Triana]
- Continue record of changes in total solar irradiance over two solar cycles [SORCE]

What we need to know

- Nature and timing of stratospheric ozone recovery
- The effects of climate change on stratospheric ozone amounts
- Sources and sinks for greenhouse gases and aerosols
- Effects of chemical and climate change on global and regional air quality

What is required

Characterizing long-term changes in:

- **Total column and profile abundance of ozone**: precise, continuous (overlap is critical), long-term record for determining stratospheric ozone trends
- **Atmospheric temperature and water vapor**: controlling climatic parameters for atmospheric chemistry and dynamics
- **Global abundance of ozone destroying compounds**: measurements needed to determine the halogen budget and verify compliance with regulations
- **Selected representative species in critical classes:** determine stratospheric ozone production and loss with a subset of radical, reservoir and tracer species
- **Global distribution of greenhouse gases:** in order to quantify sources and sinks for prediction of burdens and verification of emissions (difficult for species with large natural sources)
- **Global distribution of tropospheric ozone, aerosols and their precursors**: high spatial and temporal resolution

What is required

Understanding:

- Variations in stratospheric dynamics driven by climate change
- Processes which govern the amounts and pathways of pollution transported over global-scale distances
  - **Convection** which plays a key role in vertical mixing and ultimate global distribution of pollutants; understanding is complicated by geographical and seasonal variations
- Quantification of the sources and sinks of tropospheric ozone and its key precursors
  - Quantification of **combustion and lightning,** as a source of nitrogen oxides, key precursors for tropospheric ozone
  - Quantify **stratosphere/troposphere exchange** as a source of tropospheric ozone
- Chemical and microphysical processes that control the formation of polar stratospheric clouds and tropospheric aerosols

What is required

Predicting:

- **Long-term and mean seasonal changes** in atmospheric composition with emphasis on ozone and other greenhouse gases
- **Effects on stratospheric ozone** of transient climate variations such as El Nino/Southern Oscillation and North Atlantic Oscillation/Arctic Oscillation
- **Regional pollution events** taking into account long-range transport of pollutants

What we propose to do

Systematic Observations

- **Total column ozone:**

  QuikTOMS ⇒ OMI ⇒ possible bridge mission ⇒ NPOESS

- **Vertical profile ozone and aerosols:**

  SAGE III (Meteor3M, ISS, FOO) ⇒ Stratospheric Chemistry Mission

- **Selected radicals, reservoirs and tracers:**

  EOS Aura ⇒ Stratospheric Chemistry Mission (reduced sampling after Aura)

- **Solar irradiance:**

  SORCE ⇒ possible bridge mission ⇒ NPOESS

- **Systematic ground-based measurements:**

  Remote-sensing measurements for trends and satellite validation

  High-frequency in situ measurements of ozone-depleting compounds and greenhouse gases

What we propose to do
Stratospheric Chemistry Mission

- Monitoring of stratospheric and upper tropospheric temperature, aerosols, and key trace gases in the tropical, mid-latitude and polar stratosphere. The ability to monitor new chemical compounds as released into the atmosphere. Provide a bridge of column ozone measurements to NPOESS.
- Minimum measurement set includes: Temperature, aerosol surface area, O_3, HNO_3, $ClONO_2$, HCl, N_2O, CH_4, H_2O, ClO.
- Daily maps of temperature and ozone with a minimum vertical resolution of 2-3 km from the upper troposphere to 55km with a horizontal resolution of 4° latitude by 5° longitude. Lower vertical and horizontal resolution for the other trace gases. Precision of the measurements must be 10% for all trace gases except for ozone and temperature where the precision should be 1-2%.
- Nominal missions must maintain the basic elements of long term monitoring of the stratosphere begun by Nimbus 7/ SAGE/ UARS/ ATMOS/ EOS Aura systems.

What we propose to do:

Exploratory Tropospheric Chemistry Missions

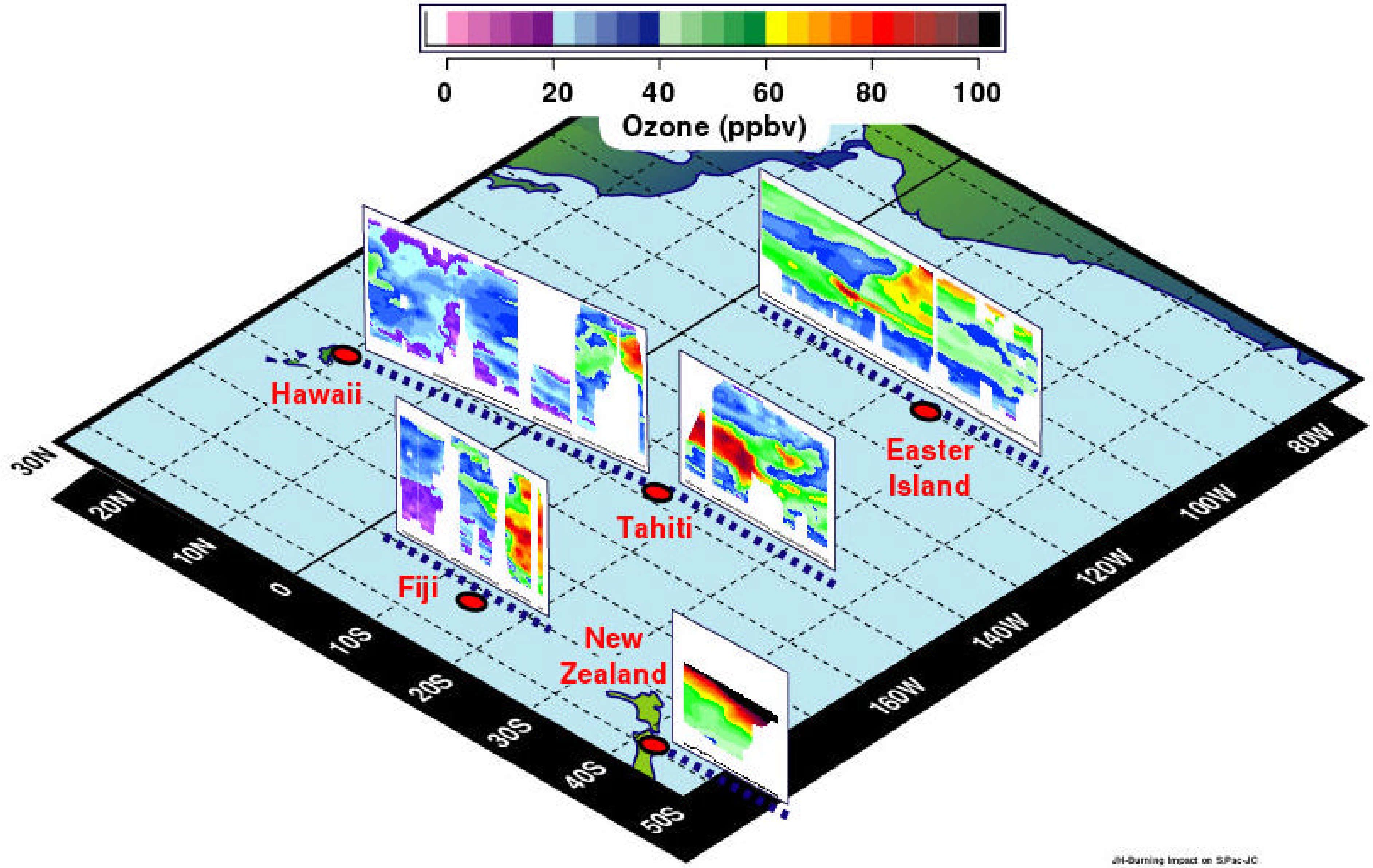
- **Lidar observations from low Earth orbit**

  High vertical resolution to observe ozone and aerosols layers, and quantify the chemical, transport and radiative consequences of these vertical structures

- **Spectral imaging from geostationary, L-1 and L-2 orbit**

  High temporal and horizontal resolution to observe rapidly evolving chemical events and quantify export from large source regions to the global atmosphere

Impact of Biomass Burning on the South Pacific



JH-Burning Impact on S.Pac-JC

QuickTime™ and a
Video decompressor
are needed to see this picture.

What we propose to do

Technology Investments

- Advanced **focal plane arrays** enabling high dynamic range, high spatial resolution, radiation tolerant UV, Visible, NIR and IR imaging at moderate detector temperatures
  - Geostationary and L-1 tropospheric observations

- High-power **UV lasers** for global ozone measurements with high vertical resolution
  - Low Earth orbit

- **IR lasers** for active remote-sensing of column and profile global CO_2
  - Low Earth orbit

- **Deployable telescope** systems to enable advanced space-based lidar missions and for spectral imaging from distant orbits such as geostationary, L-1 and L-2
  - Low Earth orbit, geostationary, L-1 and L-2

What we propose to do

Research and Modeling

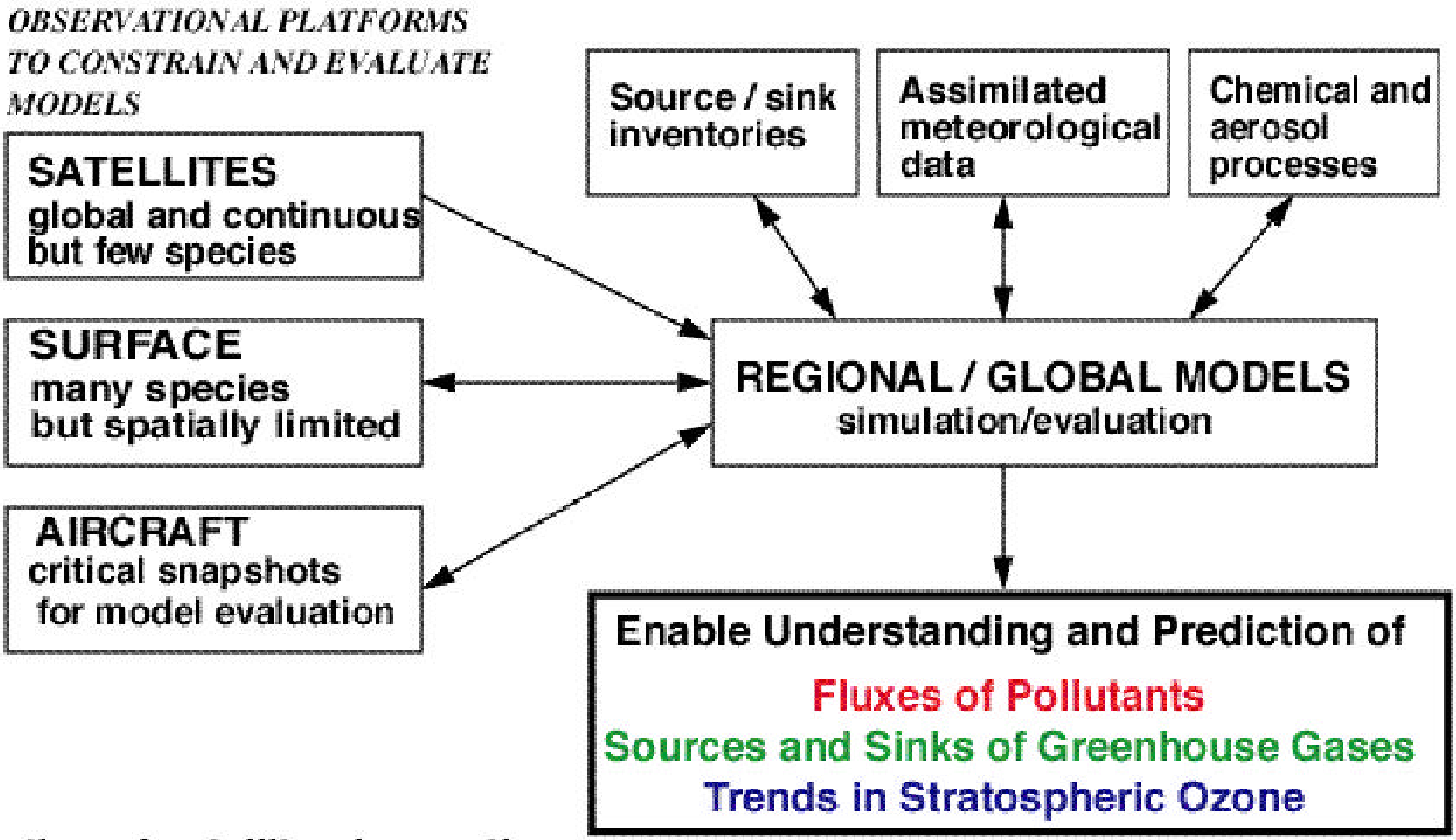
- **Atmospheric Chemistry Modeling Initiative** to provide a model framework for process algorithm intercomparisons

- **Data assimilation** to provide tools for testing models against observations and process understanding

- **Field campaigns** combining the calibration / validation goals of space-based sensors and the requirements for detailed process studies
  - **Examples:** SOLVE, Trace-P, and plan for EOS Aura campaign ⇒ address Aura calibration/validation and processes that control climate change influences on atmospheric chemistry and dynamics

- **Laboratory studies**
  - Photochemistry and kinetics to assess the residence time and products of new industrial chemicals in the atmosphere and provide important model input parameters
  - Specialized fundamental spectroscopy to enable advances in atmospheric remote-sensing

NASA's Comprehensive and integrated approach to atmospheric chemistry and chemistry-climate interaction research



Integration of satellite observations,
aircraft measurements,
surface measurements,
and large-scale models